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Estimating Nutrient Loss from Crop Residue Fires

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In spring and during some fall harvests, there can be accidental fires that burn the crop residue from a field or from part of a field. Although corn residue is most susceptible to accidental burning, wheat residue is also vulnerable, and to a lesser extent so is soybean residue. Dry, windy conditions, along with large amounts of residue, provide the conditions for an outbreak of accidental burns. After the fire, the main concern is what was lost in nutrient value, or "What went up in smoke"?

This publication discusses nutrient loss from a residue burn, average nutrient levels in residue, how to calculate nutrient economic loss, and other considerations.

In general, when there is a burn most nitrogen (N) and sulfur (S) in the residue are lost, while mineral nutrients, such as phosphorus (P) and potassium (K), are retained. A Manitoba laboratory studied wheat, oat, and flax residue burned in an uncovered container (Heard et al. 2001). After the burn, the remaining ash was collected and weighed. Much of the N and S was oxidized and lost as volatile gases, while the mineral elements (e.g., P and K) remained in the ash. The study showed N losses of 98 to 100%, S losses of 75%, P losses of 21%, and K losses of 35%. N, P, K, and S were the primary nutrients measured. The researchers speculated that the P and K lost resulted from smoke and ash that escaped from the burn container. In a field burn, some of this ash may be redeposited onto the field, depending on wind and other environmental factors. Other mineral nutrient loss could be assumed to be similar to P and K and would have minimal economic consequences in South Dakota.

CALCULATING NUTRIENT LOSS

To calculate economic loss, estimate both of the following:

1. The amount of residue in the field.
2. The concentration of nutrients in the residue.

√ *In the examples that follow, assume that most of the P and K remain on the field after the residue fire. Also assume that 100% of the N and 75% of the S were lost.*

1. Estimating amount of residue

For most crops, the weight of residue is roughly equal to the dry grain bushel weight, and most growers know the

Table 1. Average grain yield, stover/straw yields, and nitrogen (N), phosphorus (P2O5), potassium (K2O), and sulfur (S) contents for stover/straw, Brookings, SD[1]

Crop	Grain yield	Stover/straw yield[2]	Dry bushel weight[3]	Nutrient content of stover/straw (%)			
	bu/A	lb/A	lb/bu	N	P_2O_5	K_2O	S
Corn	155	7,571	47.6	0.60	0.20	1.22	0.08
Soybean	48	4,252	52.2	0.58	0.20	0.92	0.13
Wheat	62	3,756	52.2	0.57	0.18	1.73	0.12

[1] Woodard and Bly, 2004-2006 SDSU.

[2] Dry matter basis. Includes most of the above ground portion of the plant stover/straw remaining directly after grain harvest.

[3] Assuming standard bushel weights of 56, 60, and 60 lb/bu and standard moisture of 15, 13, and 13% for corn, soybean, and wheat, respectively.

grain yield from a harvested field. Therefore, to calculate the amount of residue, multiply the field's grain yield by the dry bushel weight (dry bushel weights of corn, soybean, and wheat are listed in Table 1).

Example, part 1:
Corn at 150 bu/a (corrected to 15% moisture) weighs 47.6 lbs/bu on a dry basis. Therefore, 150 bu/a x 47.6 lbs/bu = 7,140 lbs of dry grain per acre, and the residue would be estimated at the same weight (7,140 lb/a).

2. Estimating residue nutrient content

Estimating the nutrient content of the residue is also accomplished by using the values in Table 1 (the table's residue nutrient concentration values represent a 3-year average from a study near Brookings, SD). Nutrient concentrations in fresh residue are dependent on many factors, including soils, nutrients applied, plant health, and environment.

Example, part 2:
To estimate residue N and S amounts for Example, part 1 (above):

First, multiply the estimated residue weight by the nutrient content percentage (expressed in decimal form) from Table 1:

N: 7140 x .006 = 43 lb N/acre
S: 7140 x .0008 = 6 lb S/acre.

Second, assign a dollar value to the lost nutrients. Typically, a dollar value is assigned by determining the grower's average fertilizer nutrient price on a per-pound basis. For example, if urea fertilizer (46-0-0) costs $425 per ton, then $425/(46 x 20) = 425/920 = $0.46 per lb of N. Assuming S is $0.20 per lb, the calculation for total nutrient value lost per acre is as follows:

N: 43 lb N/a x 1.00 (% loss) x $0.46 = $19.78
S: 6 lb S/a x 0.75 (% loss) x $0.20 = $0.90

Total value of N and S loss = $20.68/acre

The above calculations contain a number of assumptions, and although not exact, they will provide a reasonable estimate in most situations. It should also be emphasized that this is the long-term economic loss of nutrients. The immediate replacement of these nutrients for producing the next crop is not necessary. In fact, because of the higher temperatures, the bare soil will warm more rapidly and over the season may produce more plant-available N from soil organic matter breakdown. In addition, because of less residue there is often less short-term immobilization of N, and therefore there is more available N for the plant.

OTHER CONSIDERATIONS

After the fire, weather conditions often play a role in nutrient loss from the field. For example, high winds can blow ash from the field or can pile the ash into drifts. Heavy rains can move some of the ash from the field or relocate it within the field. In addition, soil erosion from both wind and water can occur more readily when the residue cover is destroyed and the soil is left exposed.

The amount of residue harvested and its nutrient content may change with time in the field. The amount and nutrient content of the residue is hard to approximate and depends on factors such as time, tillage, grazing, temperature, precipitation, and possibly other factors. Standing residue is much slower to decompose than is material that is in contact with the soil.

The completeness of the burn also needs to be assessed. In some cases the residue near the soil surface may not be destroyed or areas of the field may not have burned.

POTENTIAL SOIL ORGANIC MATTER LOSS

Many growers inquire about the value of the potential organic matter that is lost; this value is also difficult to estimate. The removal of a year's residue vs. leaving the residue cannot be measured with current laboratory organic-matter tests.

Using some standard values, the 7,140 lb/a of residue from the preceding example can *potentially* raise soil organic levels from 0.03 to 0.06%. "Potentially" is used as a term because in a tilled corn-soybean rotation organic matter levels tend to slowly decrease or change very little. However, removing residues can increase the decline.

A western Canada study where the cereal residue was burned annually for 19 years showed average annual soil organic matter declines of 0.03 and 0.07% (compared to plots where residue was not burned) for the study's two sites (Biederbeck et al. 1980). Iowa State had previously estimated $1/acre for the organic-matter value from a 1-time corn residue loss under a tilled corn-soybean rotation (Sawyer 2000). At 2009 prices, at least $2/acre would be suggested under tilled conditions, and $4/acre under no-till—where some research has shown more efficient conversion of residue carbon to soil organic matter compared to tillage (Duiker and Lal 1999; Clapp et al. 2000). In addition, no-till fields usually have residue from the previous year(s) that may be able to burn. With carbon trading possible, perhaps a more standardized economic value for carbon or organic matter loss can be determined.

FERTILIZER LOSSES

In some instances, fertilizer may have been applied just prior to a residue fire. If rainfall or tillage has occurred between the fertilizer application and the burn, nutrient losses from the fertilizer should be minimal. Urea will decompose to ammonia and nitrogen oxide gases with temperatures greater than 275 degrees F. Soil-surface temperatures from wheat-residue burns have been measured from 150 to 750 degrees F, with averages of 318 to 700 degrees F (Heard et al. 2001; Rasmussen et al. 1986). Therefore, N losses will likely be high when residue completely burns. If the fire occurs after the urea pellet has dissolved, losses may be less. The phosphorus fertilizers DAP (18-46-0) and MAP (11-52-0) decompose at temperatures of 310 and 375 degrees F, respectively. However, since the loss of phosphorus is low from organic P in residue sources, it is assumed to be low with inorganic P fertilizer sources as well.

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